07

II

7.6-10.458
CR-148589

Submitted by:

Alaska Cooperative Wildlife Research Unit
University of Alaska
Fairbanks, Alaska

Contract No.: NAS5-20915

Investigation No. 22280

Title: Use of LANDSAT imagery for wildlife habitat mapping in northeast and eastcentral Alaska

Type II Progress Report No. 4 -- August 20, 1976

A. Problems: There are problems with results of two of the scenes analyzed. Analytic results for scene 1734-20471 are erratic and inconsistent. No reasonable patterns corresponding to vegetation types or geographic features are present. Fortunately, this was a "patchwork" scene used for coverage of small gaps between major scenes in the analysis. Consequently, this development will not materially affect overall project objectives. This scene contains a thin, relatively uniform layer of haze and small, discontinguous blocks were analyzed to provide desired coverage between other scenes. Random sampling within these blocks was obtained and subsequently combined for the clustering procedure. Non-uniform haze density from block to block is probably responsible for the erratic results. Therefore, the scene is under re-analysis and data from each block will be processed separately.

The other scene (1422-20203) covers the southeastern portion of Game Management Unit 20 and is dated 18 Sep 73. Results for this scene are not entirely unsatisfactory (see Table 3). Results for coniferous forest classes, water classes, and unvegetated classes in the analysis were satisfactory. However, results for other classes such as high brush, deciduous forests, sedge meadows, and tundra classes were inconsistent. At the time of analysis, problems with data from this scene were noted. The dynamic range of the MSS data was quite limited relative to other scenes and the initial clustering procddure generated only eight analytic classes. Consequently, clustering criteria were liberalized by reducing sigma levels and increasing the Euclidean distance permissible between clusters. Still, this revised procedure generated only a dozen analytic classes. We conclude that early vegetational senescence in Alaska is responsible for these results and scenes dated later than about 5 Sep are unsuitable for vegetational analyses. Shortly after this date, vegetational senescence prevents satisfactory discrimination of non-coniferous vegetation types with LANDSAT MSS data. This conclusion is supported by subsequent analyses attempted by another investigator. where he attempted analyses of an early October scene near Yakutat and a late September scene near Anchorage produced similar results.

B. Accomplishments: Aerial photo reconniassance data has been obtained to define analytic results for five LANDSAT scenes (1407-20374, 1408-20430, 1422-20203, 1771-20513, and 1771-20515). Based on these data, preliminary definition of analytic classes is presented in Tables 1 through 5. Results are generally satisfactory except for scene 1422-20203 which is discussed above. Ground truth field activity is still in progress and will continue until early September.

22280

C. Significant results: Indications are that Alaskan scenes dated later than about September 5th are unsuitable for vegetational analyses. Such fall data exhibits a limited dynamic range relative to summer scenes and the informational content of the data is reduced such that discriminations between many vegetation types is no longer possible.

D. Publications:

LaPerriere, A.J. 1976. Use of LANDSAT Data for Vegetation/Habitat Mapping Proc. 27th AAAS Conference (In Press.)

_____________ and P. C. Lent. Caribou feeding sites in relations to snow characteristics in Northeast Alaska. Arctic (In press).

E. Recommendations: none

F. Funds Expended: $53,595

G. Data Use:

H. Aircraft Data: None

Table 1
Feature Classes on Scene 1407-20374

Cluster Symbol	Vegetation Type
1	Undefined
2	Spruce Forest
3	Spruce bog
4	Wet sedge meadow
5	Balsam Poplar
6	Undefined
7	High brush
8	Water
9	land/water interface
A	High brush
B	gravel and rock
C	Tussock meadow
D	Undefined
E	Alluvial silt
F	Deciduous Forest
G	

Table 2
Feature Classes on scene 1408-20430

Cluster Symbol	Vegetation Type
1	small deciduous trees, tall brush
2	spruce heath and brush
3	spruce, deciduous trees, brush mixture
4	alluvial gravel
5	high brush
6	mature spruce forest
7	deciduous forest and/or high brush
8	clear water
9	turbid water
A	wet silt/shallow water
B	sparsely vegetated gravel
C	deciduous dominant mixed forest
D	turbid water
E	bare ground
F	wet alluvial silt

Table 3
Feature classes on scene 1422-20203

Cluster symbol	Vegetation Type
1	rock
2	sedge meadow
3	mixed forest
4	spruce forest
5	
6	shallow water or mud
7	rock
8	
blank water	
9	deciduous
A	vegetation
.	
B	
C	
D	alluvial silt

Table 4
Feature classes on scene 1771-20513

Cluster Symbol	Vegetation Type
1	
2	black spruce, blueberry heath, some willow
3	small deciduous trees and/or high brush
4	mixed coniferous-deciduous forest
5	turbid water
6	mixed coniferous-deciduous forest
7	spruce dominant mixed forest
8	alpine tundra
9	water
A	aspen-birch stands
B	water
C	(rare)
D	spruce forest
E	mature spruce
F	
G	deciduous forest (birch-aspen)
H	Unvegetated ground
I	spruce heath/alpine tundra
J	sand bar, gravel pit
K	open sedge meadow/alpine tundra

Table 5
Feature Classes on scene 1771-20515

Cluster Symbol	Vegetation Type
1	moderately dense to dense spruce
2	sparse black spruce heath, tussocks in ground cover
3	(rare)
4	deciduous (birch and aspen)
5	water
6	moderately dense deciduous
7	dense spruce forest
8	mixture - meadow, brush, spruce heath
9	silty water
A	silty water
B	alpine tundra, gravel and vegetation
C	(rare)
D	(rare)
E	(rare)- water
F	mixture - brush, spruce heath
G	mixture - open meadow, brush, spruce
H	silty water or mud
I	open meadow, tussocks, low brush, willows
J	silty water or mud
K	(rare)
L	bare ground, mud, some low vegetation
M	rare

Use of LANDSAT Data for Vegetation/Habitat Mapping

A.J. La Perriere, Ph.D.*

***Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks, Alaska 99701**

Vi

INTRODUCTION

LANDSAT - A and LANDSAT - B are satellites formerly called ERTS - and ERTS - 2. These satellites were initially expected to be experimental ones and the first two of the Earth Resource Observation Satellite or EROS series. The principal objective of the EROS program is to routinely obtain satellite data which my be used to monitor earth resources. The original intent of the LANSAT series was to study the feasibility of resource assessments with these data and modify sensor capability to accomplish this with maximum effectiveness. Results of these investigations would be used in design modifications for the operational EROS satellites scheduled to follow the LANDSAT series. However, results of initial investigations were so favorable that these satellites are no longer considered experimental even by NASA. It is true that design modifications are being incorporated to forthcoming satellites but existing data are being widely used by operational resource management agencies.

Multispectral scanner systems are used as sensing devices in the LANDSAT satellites. These devices sweep or scan somewhat like radar and simultaneously measure reflectance in four discrete regions of the electro-magnetic spectrum. Two of these regions are in the range of visible light while the other two are in the near-infrared portion of the EM spectrum. The earth surface area for which a given set of these four reflectance measurements correspond is called a picture element or pixel. Pixel size varies somewhat but over interior Alaska is about .5 ha or 1.2 acres. These data are organized in blocks or scenes which consist of about 7.5 million pixels. Each scene is approximately 100 nautical miles on a side and provides earth coverage of about 10,000 nautical miles squared.

These data are available in a variety of formats such as photographic products or computer compatible digital tape. Correspondingly, a variety of methods and techniques may be employed for analysis of these data. The method selected depends primarily upon analytic objectives. For example, visual interpretation of photographic products would be the most inexpensive and effective technique for such tasks as mapping recent wildfire burns, lake and river mapping, or delineation of broad general vegetation types. Conversely, computer processing of LANDSAT data in digital tape format is necessary for tasks requiring more subtle discriminations. With these latter techniques, the data are analyzed using multivariate procedures. The four reflectance values associated with each pixel are evaluated statistically and statements indicating the probability that that the pixel belongs to a certain class of target objects may be calculated. Such decision algorithms sort or classify pixel by pixel thus assigning each pixel to one of the analytic classes. Results of this classification procedure are stored on a digital tape and this tape may be used to produce a line printer map where each analytic class is assigned a different symbol. Alternately, the tape may be used to produce a photographic product where each class is assigned a different color or gray level.

The purpose of this paper is to briefly describe renewable resource applications of these data in Alaska. And, in particular, wildlife habitat applications.

<u>Feasibility Study</u> - A study funded by NASA began in 1972 and was completed in early 1974. The objective of this study was to determine the feasibility of applying LANDSAT data to wildlife management tasks in Alaska, particularly certain aspects of caribou biology, and to develop methods and techniques for application of these data. One facet of the investigation demonstrated that traditional migratory routes correspond to corridors of earliest snowmelt. Other results indicated the feasibility of vegetation/habitat mapping with LANDSAT data and maps of 7,500 miles squared of caribou rangelands in northeast

Alaska were prepared. The cost of this map .ng effort was approximately $20,000 or roughly $2.66 per square mile.

Calista Analysis - This project was initiated in March of 1974 and completed by October of the same year. The analysis was principally funded by Calista Corporation but subsidized by the U.S. Fish and Wildlife Service. Objectives of this analysis were to produce vegetation/resource maps of the 58,000 miles squared of Calista Corporate region. Vegetation maps at 1:250,000 scale were prepared and used as a basis for various resource theme interpretations such as timber value or habitat value for several wildlife species. These products were immediately utilized in native land selections and subsequently for long term land-use management planning. The total cost of the analysis was approximately $100,000 or about $1.70 per square mile.

Moose Habitat Analysis - This analysis was initiated in early 1975 and is scheduled for completion by early 1977. The principal objective of the project is to map the moose habitat of Game Management Unit 20, a 50,000 square mile area of east central Alaska. This analysis and the ones which follow employ a modified cluster classification technique. With this method, a random sample of 2 to 3 % of the data are extracted from the LANDSAT data matrix. These data are then cluster analyzed to about 25 spatial and spectral cluster classes. The data in the resulting cluster classes are used to generate Gaussian quadratic discriminant functions which are the basis for the maximum likelihood classification procedure. In this procedure, the probability that each pixel belongs to one of the cluster classes is calculated. The maximum likelihood decision is then carried out and each pixel is classified or sorted to one of the cluster classes. The results of this classification procedure are stored on a new digital tape. From the classified tape, either line printer maps or color photographic maps may be produced. Table 1 illustrates results obtained in the analysis of scene 1408-20435. The cluster analysis produced twenty-six classes but, of these, only twenty-five were defined. The remaining four classes were rare and sporadically distributed so could not be satisfactorily defined by field cre s. The twenty-two defined classes were evaluated in terms of relative importance value to moose in winter and summer. All classes judged to have the same relative value were assigned the same color. Color photography products were then prepared from the classified digital tape (Slide 1). This slide shows a portion of results on the Tanana Flats near Blair Lakes. The color assignment is for summer habitat value. Several classes of decidous trees and high brush willow are assigned a light green color. Several classes of poor growth for black spruce were assigned the brown shade. Dense stands of good growth from spruce were assigned the darker green shade. Clear water categories were assigned blue, silty water was assigned a tan shade, and unvegetated areas were assigned white. However, these white markings delineate trails, small stream channels, and selected contour lines. These were digitized into the data matrix for geographic reference. The second slide for winter habitat (Slide 2) has essentially the same color assigment except high brush willow was isolated from the other classes of deciduous vegetation and was assigned the color red.

This project is scheduled for completion by the end of the year at which time 1:250,000 scale color products will be completed. Total cost of the analysis is projected at about $[illegible]0,000 or $1.40/square mile.

Northwest Alaska Analysis - This project began early this year and is scheduled for completion by mid-1977. Funding has been provided by the Sierra Foundation and project objectives are to map and evaluate the rangelands of the Arctic Caribou Herd. This area encompasses approximately 60,000 square miles and total cost is projected at $75,000 or about $1.25 per square mile.

Seward Peninsula Analysis - This project began more recently and is jointly funded by the U.S. Fish and Wildlife Service and the U.S. National Park Service. Project objectives are to map and evaluate caribou-reindeer rangelands on the Seward Peninsula and selected adjacent areas comprising roughly 20,000 square miles. Mapping costs have not been calculated but should be approximately equivalent to costs on the Northwest Project.

Summary and Conclusions

Although designed to be an "experimental" satellite, LANDSAT has become an operational resource management tool. It is being used increasingly by resource management agencies and a second LANDSAT has been launched thus providing coverage of every point on earth every nine days.

The technology associated with the use of these data has developed rapidly over the past few years and this development is continuing. Specialized computer systems are now being marketed and their sole function is to process this type of multispectral data. The progressive development and application of mathematical procedures for classifying this data with greater accuracy is a subject for several papers in itself in addition to many biological questions which are presently being explored. For example, what is the relation of phenology to feature discriminations? If one wishes to discriminate birch from aspen, should a late spring scene, an early summer scene, a mid-summer scene, or an early fall scene be selected? These questions and many more like them are presently under investigation. Therefore, analytic costs can be expected to continue decreasing while the accuracy and utility of analytic results continues to increase.

Although this technical evolution is still in rapid progression, the current state of technology is such that an increasing number of resource management agencies are utilizing existing capabilities for resource assessments and management proposals. To date, these analyses cover about 180,000 square miles of Alaska or approximately 30% of the state's landmass. A number of smaller states such as New York, Ohio and South Dakota have been surveyed in their entirety using these techniques. The reasons for this explosive utilization of these data are that large areas can be analyzed

in a relatively short time, results are current and, in many cases, superior to existing information, and the obvious cost benefits.

For example, conventional air photo analysis of the Calista Corporate Region was considered. The low bid for such an analysis was submitted by a firm in the northwest United States. That contractual bid exceeded $2 million dollars and would have required 3 years to complete. This compares with $100,000 and 7 months using LANDSAT data.

****

Caribou Feeding Sites in Relation to Snow Characteristics in Northeast Alaska

Arthur J. LaPerriere[1]

Peter C. Lent[2]

Abstract

Caribou select areas of relatively shallow snow for winter feeding. Selection operates on at least two levels: a broad area and a micro-site selection. Hardness of the snowpack also seems to exercise some influence on caribou winter feeding site selection but the relationship is more complex than simple inverse proportionality. In most cases, the mean integrated Ram hardness values of snowpacks in caribou winter feeding areas were under 85. However, areas of relatively shallow hard packed snow that is easily fractured into slab-like pieces may provide access to vegetation at lower energy cost than would be predicted from Ram hardness values. Alpine feeding areas in the Porcupine Lake Basin of northeast Alaska had this type of snowpack in the winter of 1972-73. In typical taiga winter range, caribou selectively utilize areas where snow depth is less than 50 cm.

[1]Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks

[2]U.S. Fish and Wildlife Service, Boulder, Colorado

INTRODUCTION

The characteristics of snow cover have often been acknowledged as a critical factor influencing the survival and well being of ungulates in the arctic and subarctic (Formozov 1946; Pruitt 1959; Henshaw 1968; Kelsall and Telfer 1971). This paper reports results of snow measurements on caribou winter ranges in northeast Alaska.

METHODS

Data were obtained during early spring of 1972 and late winter of 1973. In both years, aerial reconnaissance flights began in late February or early March to determine the location and approximate numbers of wintering animals. On these flights, winter feeding areas were noted as well as conspicuously unutilized areas which appeared "trackless".

During both years, the snow cover in the Chandalar and Junjik Valleys was extensively cratered by wintering bands of caribou. In April of 1972, a field camp was established on the northwest shore of Anvil Lake (68°23'N; 145°40'W) in the Junjik Valley. Five feeding areas which had been used by caribou during the preceding 24 hours were selected for data collection (Table 1). Feeding areas, as defined here, are sites of extensive cratering activity surrounded by relatively undisturbed areas where craters are of conspicuously lower density or entirely absent. In general, such feeding areas have shallower snow depth than surrounding areas in the valley bottom.

This has been previously reported (Henshaw 1968; Pruitt 1959; Formozov 1946).

Within these feeding areas, the depth of craters and adjacent undisturbed snow was measured. The depth of craters was determined by placing a Ramsonde penetrometer shaft at the deepest part of the crater and placing a ski pole horizontally across the adjacent undisturbed snow surfaces (Fig. 1). Crater depths were then read to the nearest cm on the penetrometer scale.

Caribou were observed to throw snow out of only one side of most craters, and, normally, this was on the side of their approach. On the opposite side, the craters had a clean edge of undisturbed snow. The penetrometer was placed approximately 50 cm from this clean edge on undisturbed snow surface and pushed down through the snowpack to the ground surface. Snow depth was read to the nearest cm on the penetrometer scale.

Statistical methods used for data analysis are described in Steel and Torrie (1960: 73-75; 78-79). With the exception of one area, all observations were paired, i.e. each crater depth was associated with a particular depth measurement of adjacent undisturbed snow.

In March 1973, snow data were obtained for seven areas in northeast Alaska (Table 2). Five were located in general areas utilized by wintering bands of caribou. The other two areas were nearby upland plateaus which were conspicuously unutilized by caribou. At the five areas utilized by wintering caribou, the same measurements as described above were obtained.

Additional data related to depth and hardness of the snowpack were obtained on all seven areas. These consisted of sampling transects within both the feeding areas and adjacent areas which were uncratered. The transects

were approximately 400 m in length with ten Ramsonde profiles spaced about 50 m apart. At each sample point, data were obtained which permitted calculation of the integrated Ram hardness of the snowpack (Benson 1962; Test Lab 1970). This value is correlated to the density/water equivalent of the snowpack (Keeler 1969; Alford 1967) and, presumably, to the amount of energy required to dig through that snowpack. No transect data for adjacent undisturbed areas were obtained at Porcupine Lake or Wolf Lake because deteriorating weather conditions forced us to terminate our data collection. Transect data were also obtained at two areas conspicuously unutilized by wintering caribou.

RESULTS

The mean depths of adjacent undisturbed snow were greater than mean crater depths at all five feeding areas visited in 1972 (Table 3). The differences were highly significant for the four areas where observations were paired but the differences for the unpaired observations from Area III were significant at only the 0.1 level.

Similar results were observed in the 1973 data (Table 4). The only site where the differences were not highly significant was Porcupine Lake.

Mean snow depths measured along Ramsonde transects were less within feeding areas than in adjacent uncratered areas (Table 5). Integrated Ram hardness values were lower in feeding areas than in adjacent uncratered areas (Table 6). However, mean snow depths at the conspicuously unutilized

upland plateau areas were less than the Wolf Lake feeding area (Table 5) and mean integrated Ram hardness values at these upland plateau areas were lower than at the Porcupine Lake feeding area (Table 6).

DISCUSSION

Pruitt (1959) and Henshaw (1968) have both suggested that snow depths of 50 to 60 cm form a critical limit to caribou activity. Similarly, Lent and Knutson (1971) reported that reindeer on Nunivak Island rarely dug through more than 50 cm and often abandoned craters in deeper snow before reaching vegetation. These findings agree closely with Soviet findings for reindeer activity (Avranchik 1939; Formozov 1946; Nasimovich 1955). These authors reported that caribou and reindeer selectively feed and travel in areas of shallow snow. Henshaw (1968) reported a mean snow depth of 34 cm in locations occupied by caribou whereas the mean snow depth at his random observation points was 70 cm. Both he and Pruitt (1959) suggested that caribou exhibit strong selection against areas covered by relatively deep snows and emphasized snow depth and density differences resulting from mesorelief charactersitics such as wind shadows of forest or hills.

Soviet scientists report similar findings for reindeer but Nasimovich (1955) suggests that reindeer make use of both meso- and micro-relief features to facilitate digging food from under the snow. He cites Avranchik (1939) whose observations indicated that reindeer feeding in a hillocky bog will dig for lichens only on the hillocks where the snow is shallower than depressions

between hillocks.

Tushenskii (1949) contended the mechanism of crater site selection in reindeer is olfactory. He reported convective air currents in the snowpack which, he maintained, permitted reindeer to smell forage beneath the snow. He suggests the odor is strongest where snow is shallowest and is the basis for crater site selection. Based on experimental work, Bergerud (1970) concluded that caribou were unable to detect the presence of lichens through snowcover over 25 cm thick, unless holes were present through the pack, as are made by protruding plant stems.

Pruitt (1959) postulated a "snow fence" hypothesis, wherein he maintained caribou move about the country side within the confines of "fences" of adverse snow conditions.

Our results generally support both hypotheses. In any general area, caribou seem to select sites of shallowest and softest snow for feeding activity. However, neither depth or hardness considered individually seem to determine selection of general areas where the animals winter. There are upper limits for both depth and hardness. The upper limit for snow depth is approximately 50 to 60 cm and, in a unpublished report to the Alaska Department of Fish and Game, Pegau (1964) stated, "Reindeer cannot survive on winter ranges where ice crusts thicker than 1-1/2 to 2 inches habitually form."

Beneath these upper limits of tolerance, it seemed a reasonable presumption that selection of feeding areas would be influenced by both depth and hardness.

The Porcupine Lake area seems to be a special case and atypical winter

range for caribou. The snow data obtained there are significantly different from data obtained at all other winter range areas visited. Mean integrated Ram hardness is almost twice as great as any other feeding area (Table 6) and Porcupine Lake was the only feeding area where there was no significant difference between crater depth and depth of adjacent undisturbed snow (Table 4). As regards the latter, there are two possible explanations: either the snow pack was too dense for the animals to accurately sense snow depth differences or the terrain has almost no micro-relief. Summer visits to the areas revealed there was, in fact, very little micro-relief on the ridgetop feeding area. As to hardness, caribou were observed walking and running on the snow without fracturing the upper surface, thus facilitating travel and/or escape from predators. Summer field work at Porcupine Lake in 1973 revealed the lichen crop was substantially more abundant than all other winter range areas visited. Additionally, none of the caribou pellet groups found there showed evidence of decomposition. This contrasted with all other winter ranges visited where various states of pellet decomposition were observed thus suggesting a long history of caribou use.

The snow data seem to indicate the Porcupine Lake area should not have been selected for winter use by caribou but the fact is this area was extensively utilized by caribou in the winter of 1972-73. There are at least two contradictory hypotheses which both seem plausible.

First, one may hypothesize that the advantages of easy travel and high quality abundant forage counter balance the disadvantage of digging through hard packed snow. Furthermore, hard packed snow that is easily fractured

into slab-like pieces may provide access to vegetation at lower energy cost than would be predicted from Ram hardness values (Lent and Knutson 1971). Thus, from an energy budget viewpoint, it is possible that the area was excellent winter range in that particular year.

An alternate viewpoint is that the area is marginal winter range which the animals were forced to utilize because of population pressure.

According to the normal migratory pattern of the Porcupine Herd described by Hemming (1971) and others, the maj rity of these animals occupy winter ranges in the southern Yukon Territory. In the fall of 1972, the migration to winter ranges was proceeding as usual until early October when the animals reached the Porcupine River in the vicinity of Old Crow. At that point, however, a substantial portion of the herd turned southwest and returned to Alaska instead of crossing the Porcupine River and continuing south the their usual wintering areas.

Various numerical estimates as to the number of animals involved were offerred by U.S. and Canadian biologists following the progress of the migration. Some reported 20,000 animals returned to Alaska while others suggested as many as 50,000 caribou. In any case, local residents and biologists working in the area agreed that there were many more caribou in Alaska that winter than usual.

We will not attempt to offer specific numerical estimates or speculate as to why this deviation from the normal migratory pattern occurred. There were unusually large numbers of caribou wintering in northeast Alaska during the winter of 1972-73. Perhaps the population pressures on winter ranges forced some animals to utilize marginal ranges which would not otherwise

have been grazed. This may explain use of the Porcupine Lake Basin where snow conditions were markedly different from all other winter range areas visited.

CONCLUSIONS

Caribou have the ability to select areas of relatively shallow snow for winter feeding. This selection seems to take place on several levels. First, the animals select general areas, such as a particular valley, which they occupy for at least part of the winter. Second, within these general areas, the animals select feeding areas where cratering activity is concentrated. Finally, within these feeding areas, the animals select specific sites for cratering. At all levels, this selection seems to operate toward progressively shallower snow depths. That is, the mean snow depth within large general areas which are not utilized is usually greater than the mean snow depth in general areas which are utilized by wintering animals. Within those general areas, the mean snow depth in feeding areas is usually less than mean snow depth outside the feeding areas. Finally, craters' depth is significantly less than the depth of adjacent undisturbed snow wherever the terrain has micro-relief such as hummocks or tussocks.

Lent and Utermohle (Lent 1974) reported similar micro-relief selection by reindeer on Nunivak Island. Snow depth at craters averaged 21 cm whereas randomly selected adjacent sites had a mean depth of 56 cm. The differences

for both depth and hardness were significant ($P<.05$).

The hardness of snow does seem to exercise some influence on caribou winter feeding behavior but the relationship seems more complex than simple inverse proportionality. Certain advantages, such as ease of travel and escape from predators, may accrue to animals wintering on hard packed snow particularly if they are able to fracture the snow pack easily for forage. On most utilized winter range areas the mean integrated Ram hardness of the snowpack was under 85, whereas the means for unutilized areas all exceeded 85. The two utilized areas with values exceeding 85 were also the ones with the lowest mean snow depths among the 10 areas visited.

ACKNOWLEDGMENTS

The research reported here was funded by NASA under contract NAS 5-21833, Task 7. Individuals who contributed significantly to the field effort include Mr. Averill Thayer, Manager, Arctic National Wildlife Range, Mr. Robert Pelz and Mr. Mickey Van Hatten. Dr. Sam Harbo, University of Alaska, assisted with statistical design.

REFERENCES

Alford, D. L. 1967. Estimating depth-load values in the spring alpine snowpack. Paper presented at the Western Snow Conf., Boise, Idaho, April, 1967.

Avranchik, M. N. 1939. Winter diet of reindeer in the Yamal North. Tr. Sc. Inst. of Arctic Agric., Reindeer Ind. Ser. No. 4, L.

Benson, C. S. 1962. Stratigraphic studies in the snow and firn of the Greenland ice sheet. Res. Rept. 70. U.S. Army Snow, Ice and Permafrost Res. Establ. Corps of Engineers. 93 p.

Bergerud, A. T. and M. J. Nolan. 1970. Food habits of hand-reared caribou Rangifer tarandus L. in Newfoundland. Oikos 21, 348-350.

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. Occas. Publ. No. 1, Boreal Inst., Univ. Alberta, Edmonton. 197 p.

Hemming, J. E. 1971. The distribution and movement patterns of caribou in Alaska. Wildlife Tech. Bull. 1. Alaska Dept. Fish and Game. 60 p.

Henshaw, J. 1968. The activities of the wintering caribou in Northwestern Alaska in relation to weather and snow conditions. Intern. J. Biometeor. 12(1), 21-27.

Keeler, C. M. 1969. Some physical properties of alpine snow. USA CRREL Tech. Res. Rept. 271.

Kelsall, J. P. and E. S. Telfer. 1971. Studies of the physical adaptation of big game for snow, p. 134-146. In Proc. Snow and Ice in Relation to Wildlife and Recreation Symp. Iowa State Univ., Ames. 280 p.

Lent, P. C. 1974. Ecological and behavioral study of the Nunivak Island muskox population. Unpubl. Rept. to U.S. Fish and Wildlife Service. Univ. Alaska, Fairbanks. 91 p. Typewritten.

Lent, P. C. and D. Knutson. 1971. Muskox and snow cover on Nunivak Island, Alaska, p. 50-62. In Proc. Snow and Ice in Relation to Wildlife and Recreation Symp., Iowa State Univ., Ames. 280 p.

Nasimovich, A. A. 1955. The role of snow conditions in the life of ungulates in the USSR. Unedited translation prepared for Canadian Wildlife Service by the translation service of the Dept. Indian Affairs and Northern Development. 290 p. Xerox.

Pruitt, W. O., Jr. 1959. Snow as a factor in the winter ecology of the barren ground caribou. Arctic 12, 159-179.

Steel, R. G. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw Hill Book Co., Inc., New York. 481 p.

Test Lab. 1970. The Swiss Ramsonde. Spec. Tech. Paper No. 1. Testlab Div. GDI, Inc., Chicago. 15 p.

Tushinskii, G. K. 1949. Avalanches. Moscow.

Table 1: Dimensional characteristics and description of caribou feeding areas in the Junjik River valley during April 1972.

	Shape	Size	Habitat	Location
Area I	Linear	Approx. 40mx1000m	Open spruce forest	Ridge along north shore of lake (68°23'N, 145°40'W)
Area II	Roughly circular	100m average diameter	Open spruce forest	Small hill 250m east of northeast finger of lake
Area III	Roughly circular	100m average diameter	Open spruce forest	Small hill 200m northeast of Area II
Area IV	Linear	Approx. 50mx400m	Open forest	Ridge along northwestern lakeshore
Area V	Roughly circular	300m average diameter	Treeless meadow	1000m northwest of lake

Table 2: Data collection sites in March 1973.

Areas utilized by wintering caribou	Location	General area	Areas conspicuously unutilized by wintering caribou	Location	General area
Anvil Lake	68°23'N; 145°40'W	Junjik Valley	Bulb Lake	68°01'N; 145°11'W	Upland plateau east of Chandalar Valley
Cabin Lake	68°25'N; 146°45'W	Junjik Valley			
Vettatrin Lake	68°30'N; 145°04'W	Chandalar Valley			
Wolf Lake	67°33'N; 146°11'W	Chandalar Valley	Deadman Creek	68°21'N; 145°55'W	Upland plateau south of Junjik Valley and west of Chandalar Valley
Porcupine Lake	68°23'N; 146°30'W	Alpine Basin in Philip Smith Mountains			

Table 3: Mean snow depths in April within caribou feeding areas of the Junjik Valley and results of statistical comparisons.

Area	No. of observations		Mean depth (cm)		Difference	Level of significance
	Paired	Unpaired	Craters	Adjacent		
I	44	0	39.5	46.9	7.4	.001
II	44	0	32.0	44.9	12.9	.001
III	0	46	33.2	51.5	8.3	.1
IV	44	0	38.1	48.8	10.7	.001
V	44	0	31.6	39.5	7.9	.001

Table 4: Mean snow depths at crater sites and adjacent undisturbed snow within caribou feeding areas in March 1973.

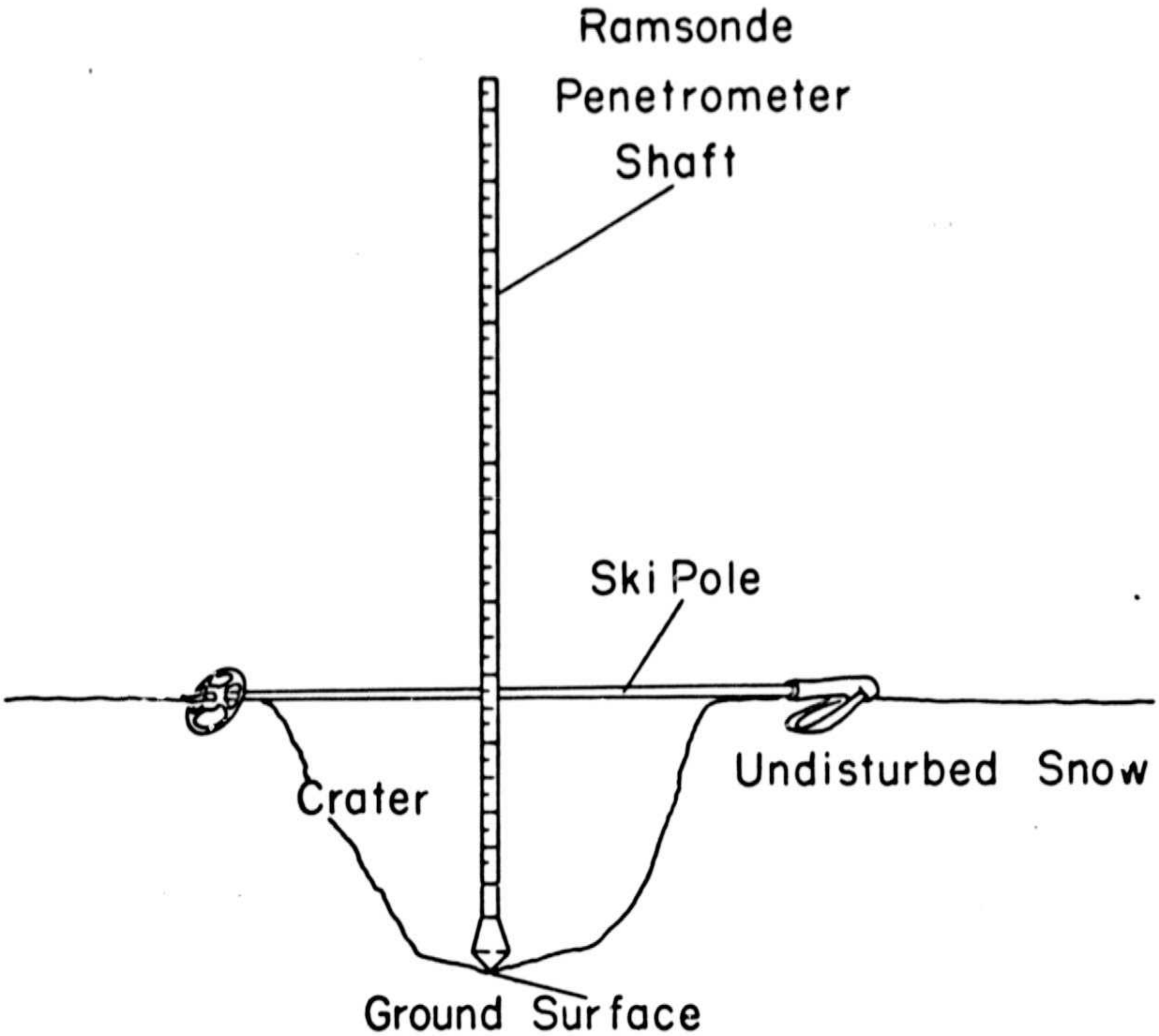
Area	No. of paired observations	Mean depth cm adjacent	Crater site	Difference	Level of significance
Anvil Lake	44	46.3	41.0	5.3	.001
Vettatrin Lake	44	48.2	38.7	9.5	.001
Cabin Lake	37	29.6	25.5	4.1	.001
Wolf Lake	44	51.7	45.9	5.8	.001
Porcupine Lake	44	37.8	35.7	2.1	n.s.

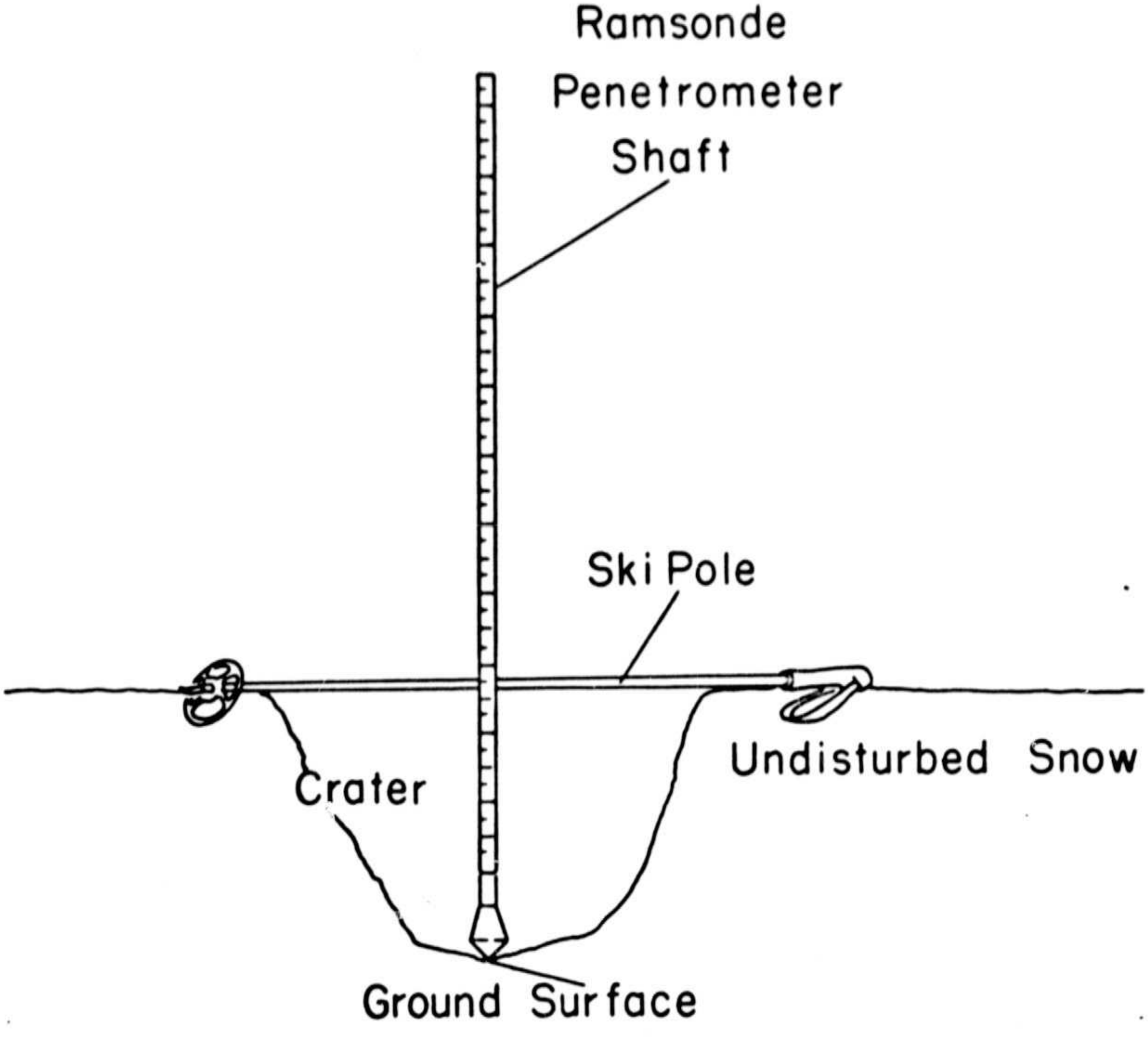
Table 5: Mean snow depths at caribou feeding areas and conspicuously unutilized sites in March, 1973.

Approximate location	Mean snow depths (cm)		Differences
	Feeding area	Uncratered area	
Anvil Lake	43.6	51.3	7.7
Vettatrin Lake	43.5	45.1	1.6
Wolf Lake	48.8	--	--
Cabin Lake	27.6	39.1	11.5
Porcupine Lake	36.8	--	--
Bulb Lake	--	50.3	
Deadman Creek	--	47.6	
Mean Values	40.1	46.7	6.6

Table 6: Integrated Ram headness values (R_i) for transects within caribou feeding areas and for conspicuously unutilized areas in March, 1973.

Location	Caribou use	Minimum R_i	Maximum R_i	Mean R_i	Variance
Anvil Lake	Feeding	44.26	118.09	74.31	531.41
Anvil Lake	None	48.90	131.61	89.78	745.93
Vettatrin	Feeding	50.10	105.91	77.71	387.25
Vettatrin	None	62.55	131.75	89.06	527.12
Wolf Lake	Feeding	35.21	118.73	82.56	488.40
Cabin Lake	Feeding	38.41	245.49	94.47	3835.58
Cabin Lake	None	48.59	464.48	223.49	24112.67
Porcupine Lake	Feeding	54.71	352.34	167.26	10352.49
Bulb Lake	None	55.55	298.09	117.80	5226.09
Deadman Creek	None	75.43	155.13	103.64	1001.63


Ramsonde
Penetrometer
Shaft
Ski Pole
Undisturbed Snow
Crater
Ground Surface


Ramsonde
Penetrometer
Shaft
Ski Pole
Undisturbed Snow
Crater
Ground Surface